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Economic and Technical Analysis of Several Heat Metering Modes: A Case Study from Beijing, China

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Abstract

Poor thermal comfort of indoor and low efficiency of heating system can always be found in the buildings with large energy consumption. This paper adopted a comparison method to carry on the energy consumption analysis of several control and operation regulation modes of heat metering heating system. A demonstration project in Tianjin was selected as an example to calculate the energy consumption of circulating water pumps of the secondary pipe network in different combinations of control and regulation, and carries on the comparative analysis. It is concluded that circulating water pumps will be the lowest energy consumption under the remote constant pressure control. And it points out the major problems existing in current, which is beneficial for scholars' further study on heat metering system.

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Keywords: Existing residential buildings; Heating system retrofit; Heat metering mode; Economic and technical introduction

1. Introduction

The energy consumption of buildings has always accounted for a large proportion of total societal energy consumption. With the rapid development of urbanization, the area of urban and rural construction increases greatly, which result in higher energy consumption. In 2013, building energy consumption accounted for nearly 19.5% of total energy consumption in China [1]. As a major building type, residential buildings accounted for 24.5% of building energy consumption. Among them, the heating energy consumption in north urban accounted for 24.0% of

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the building energy consumption [1]. Therefore, the energy intensity of urban heating in northern cities is relatively large. And it is necessary to promote the retrofit of heat metering.

Penna et al. [2] think that introducing incentives to foster solutions not economically profitable is necessary, but more efficient in terms of energy savings and indoor thermal comfort. Towards a multi-objective optimization approach for improving energy efficiency in buildings, Diakaki et al. and Asadi et al. [3-4] all corroborate the practicability of this approach and highlight potential problems that may arise. This paper is at the base of actual application. Through abundant survey in Beijing and then get the statistic of current heating systems, it summarizes the heating systems in accordance with the heat metering. Through this, this article analyzes the economy of several heats metering ways by the point of engineering economy. It appraises their economic impacts with different economic impact index at all positions and arrangements in order to get all-around and believable conclusion. But only the economy is not enough in the practice of heat metering, different people and architectures in different periods need different heat metering ways. It should consider several ingredients, such as the technological layer, to discriminate and contrast the heat metering ways. This paper used the testing data as chief source, which compared several heat metering models by economically and technologically, it obtained the optimal heat metering retrofit scheme and made a well base for the material implement of heat metering.

Nomenclature

q_v the volume heat index of the building (W/m^3)
G the hot water flow (kg/h)
V the volume of the building (m^3)
t_n the actual indoor temperature of the building (℃)
t_w the actual outdoor temperature (℃)
τ sample period of metering device (s)
A the radiator coefficient determined by experiment
b the radiator coefficient determined by experiment
F the area of the radiator (m^2)
t_p the average temperature of heat medium of the radiator (℃)
β_1 the correction coefficient of the number of the radiator
β_2 the correction coefficient of connection form of the radiator
β_3 the correction coefficient of installation form of the radiator
β_4 the other correction coefficient of the radiator
t_g the supply water temperature (℃)
t_h the return water temperature (℃)
C household annual investment cost of heat metering (Yuan / household. year)
C_t depreciation expense for metering device and pipeline (Yuan / household. year)
c_i metering device cost (Yuan)
d_i life cycle of metering device (year)
S_i household indoor area (m^2)
S_0 the total area of building heating (m^2)
C_t installation cost of metering device (Yuan / household. Year)
C_w meter counting and settlement costs (Yuan / household. Year)
α Installation coefficient (0.8)
β the meter reading and settlement price (10 Yuan / household. Year)
b number of groups of the radiator per household

2. Heat metering method for heating system

In heat metering system is a product of the market economy, the heat as a commodity, prompted heating enterprises as an economic entity to the normal operation of the means, also can promote the active energy of heat users. According to different allocation patterns, there are many kinds of heat metering methods [5].

2.1. Heat metering mode

We take heat source metering, building metering and user metering mode as the three level allocation mode. See Fig. 1.

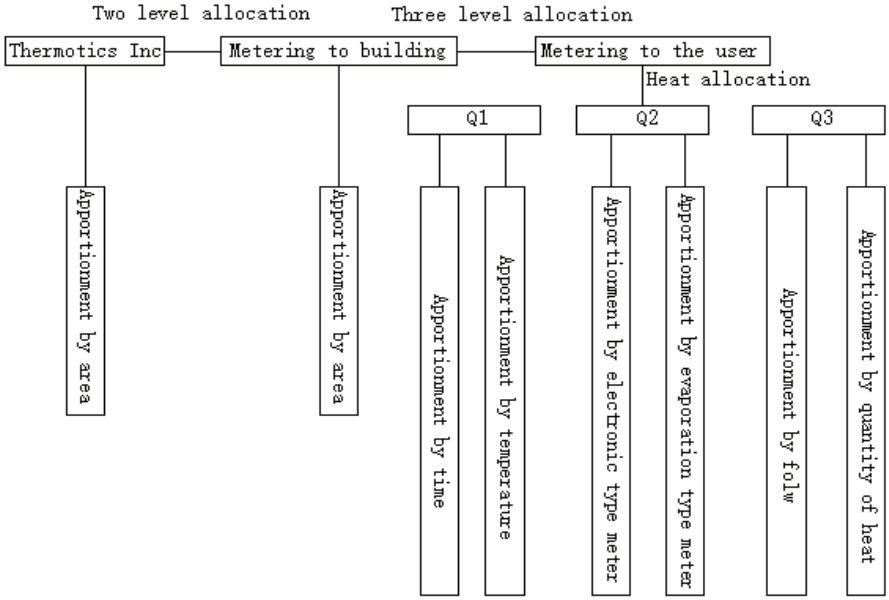

Fig. 1. Three level allocation mode

In the three level allocation mode, building total trade settlement basis is the heat metering equipment, which must be set in the building. And metering equipment of the user's and total meter of the building belongs to the allocation relationship. Moreover, heat meter of the building and heat source meter are also sharing relationship.

2.2. Allocation method

According to the above heating metering mode, there are different metering methods and heat allocation methods.

2.2.1 Metering user heat loss through the building envelope (Q_1)

In the structure of certain conditions, building heat consumption index can be regarded as a constant, the heating users through the heat loss of building envelop is related to indoor temperature, outdoor temperature and heating time. There are two methods of heat metering by this principle: room temperature allocation method and time allocation method.

$$Q_1 = q_v V \int (t_n - t_w) d\tau \tag{1}$$

This method treats the volume heat index as the instrument constant. As long as we know the indoor temperature and outdoor temperature and determine the sampling time of the instrument, we can get heat load.

2.2.2 Metering heat dissipation of radiator (Q_2)

In the certain condition of radiator, the heat dissipation of radiator is related to temperature difference between average temperature of radiator and indoor temperature. There are two methods of heat metering by using this principle: heat distribution method by evaporation heat meter and electronic heat meter.

$$Q_2 = AF\int\left(t_p - t_n\right)^{1+b} d\tau / \beta_1\beta_2\beta_3\beta_4 \tag{2}$$

From Eq. (2), as long as we know the indoor average temperature, the average temperature of heat medium of the radiator and determine the sampling time of the device, we can get the heat released by the radiator. If the measuring method for the average temperature of heat medium of the radiator is different, heat metering way is also different.

2.2.3 Metering the heat of supplying building by heating network (Q_3)

The heating load is related to supply and return water temperature and the hot water flow. There are two methods of heat metering by using this principle: allocation method by water meter and heat meter.

$$Q_3 = 1.163\int G\left(t_g - t_h\right)d\tau \tag{3}$$

From Eq. (3), as long as we know the supply and return water temperature, the hot water flow and determine the sampling time of the device, we can get the heat of supplying building by heating network. If the assumption is different, heat metering method is also different.

Although there are different ways of heat metering, it is based on the above three principles.

3. Determination of investment cost of heat metering

3.1. Heating project overview

There is an existing residential building about 2 units, 24 households. The supply and return water temperature is 85/60℃, and the heat load index is 34 W/m2. Using indoor level dual pipe heating system, each household has six groups of radiator and staircase has six groups of radiator, which are a total of 150 sets of radiators.

3.2. The demand for regulation of thermostatic valve on the hydraulic control device of the thermal inlet

In heating metering retrofit of the No. 1, heat meters are installed in stairs and indoor installs imported household heat meter. Heat cost apportion method is charged by household metering correction. In the comparison of various heat metering methods, different heat metering devices are needed to determine the investment of each method. The comparisons of metering device investment are shown in table 1.

Table 1. The investment of heat metering equipment (Unit: Yuan).

Name	Quantity of equipment	Unit price	Total price
Thermostatic valve	150	160	24000
Evaporation heat distribution meter	150	40	600
Electronic heat distribution meter	150	130	19500
Domestic household heat meter	24	800	19200
Import heat meter for household	24	1300	31200
Heat metering meter by temperature method	24	800	19200
Building heat meter	1	4050	4050
Self-operated differential	1	100	100

pressure control valve			
Hot water meter	24	70	1680

Since the service life of various devices is different, the economic performance of the scheme in the life cycle is not comparable, so the life cycle of different equipment is need to be determined, that is, the depreciation period is different. The calculation example of the depreciation period of the various devices sees Table 2.

Table 2. The investment of heat metering equipment (Unit: Yuan).

Name	Building heat meter	Heat meter for household	Evaporation heat distribution meter	Electronic heat distribution meter
Depreciation period	10	5	10	10
Name	Hot water meter	Thermostatic valve	Self -operated differential pressure control valve	Pipeline
Depreciation period	10	10	10	10

The cost of measurement and investment includes: heat metering device and purchase cost of thermostatic valve, installation fee and removal fee; reading, calculation, bill making and delivery etc. Except for the initial installation cost of the temperature heat meter method, which accounts for 50% of the heat meter price, the other installation cost of the equipment and the demolition cost of the middle replacement of heat meter are 8% of the heat meter price. While heat distribution meter need to record readings annually, meter reading fee is 10 Yuan / (year. a) and other instruments did not consider the reading meter fee. Moreover, analysis doesn’t consider the electronic heat distribution meter, data communication and storage equipment of heat metering by temperature method and installation costs.

3.3. The demand for regulation of thermostatic valve on the hydraulic control device of the thermal inlet

In the economy comparison of the heat metering method, in order to obtain each kind of investment income status of heat metering modes, which regards the main equipment used in the measurement methods as distinction points, it obtains annual heat metering investment fee. Heat metering ways are shown in Fig. 3.

Table 3. The introduction of the ways of heat metering.

Scheme	Metering method	Main metering device
A	Metering by building heat meter	Building heat meter + self -operated differential pressure control valve + thermostatic valve
B	Metering by evaporation heat distribution meter	Building heat meter + self -operated differential pressure control valve + thermostatic valve + evaporation heat distribution meter
C	Metering by electronic heat distribution meter	Building heat meter + self -operated differential pressure control valve + thermostatic valve + electronic heat distribution meter
D	Metering by domestic household heat meter	Building heat meter + self -operated differential pressure control valve + thermostatic valve + domestic household heat meter
E	Metering by import heat meter of household	Building heat meter + self -operated differential pressure control valve + thermostatic valve + import heat meter of household
F	Heat metering by temperature method	Building heat meter + self -operated differential pressure control valve + thermostatic valve + household thermometer
G	Metering by hot water meter	Building heat meter + self -operated differential pressure control valve + thermostatic valve + hot water meter

4. Annual investment cost estimation for thermal users

For the newly buildings, the heat metering method can be used for economic analysis of the above six, combined with the following formula to determine the annual investment costs of the user's heat metering [6].

$$C_t = \sum \left(\mathrm{c}_i / d_i \right) \cdot \left(S_i / S_o \right) \tag{4}$$

$$C_{\mathrm{r}} = C_z \cdot \alpha \tag{5}$$

$$C_w = \beta \cdot \mathrm{b} \tag{6}$$

$$C = C_t + C_r + C_w \tag{7}$$

In the newly built building, compared with conventional heating system, the average price differences of the indoor pipeline and radiator renewal is 10 Yuan / m2, the average metering fee of per household will increase 567 Yuan and it will increase a total of 13608 Yuan. Since the investment in each scheme is not comparable within each life-cycle period, the annual heat metering investment of the scheme is calculated for 10 years. Adopted different measurement, the annual investment of heating metering for the user can see in Table 4.

Table 4. The yearly heat metering investment.

Scheme	A	B	C	D	E	F	G
Metering device cost	26350	31550	43250	45550	57550	45550	27400
Conversion cost for metering device and pipeline (Yuan / household. year)	165	188	238	245	296	245	165
Initial installation fee (Yuan)	2108	2520	3460	3642	4605	3644	2190
Initial fixed investment (Yuan)	28458	34074	46710	49195	62154	491945	29592
Meter counting and settlement costs (Yuan / household. year)	—	130	130	—	—	—	—
Replacement cost of heat meter (Yuan)	—	—	—	22844	35804	—	—
Annual investment cost of heat metering for each household (Yuan / household. year)	376	570	715	706	906	615	386

Annual investment cost of heat metering for each household is shown in table 4, and it can be seen: D > E > C > F > B > G > A. That is, the largest annual metering investment is imported heat meter; the heat meter method of the building charged by area is the smallest investment.

5. Conclusions

In this paper, the comparative approach was adopted as the core method to carry on the economic and technical analysis of several heat metering modes for district heating system (DHS). A case study was selected as an example to discriminate and contrast the heat metering ways. Seven heats metering retrofit scheme (HMRS) were proposed after the energy efficient retrofit of building envelops. Based on the above analyses, some important conclusions could be drawn:

- At present, all the heat metering models are based on the following three items: metering user heat loss through the building envelope (Q_1), metering heat dissipation of radiator (Q_2) and metering the heat of supplying building by heating network (Q_3).
- According to the actual project, we can see that the largest annual metering investment is imported heat meter method and the heat meter method of the building charged by area is the smallest investment.
- With comprehensive consideration of technical and economic benefits, which is combined with characteristics of practical engineering, it would obtain the optimal heat metering retrofit scheme.

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